

Condition of the Regional Wastewater Conveyance System

The regional wastewater conveyance system has developed over the last 40-plus years. Most of the system has the necessary capacity to transmit wastewater flows today and in the future. However, some portions of the system are at or near capacity during periods of peak flow.¹ As the region grows over time, these portions of the system and others will not have adequate capacity to transmit peak wastewater flows to treatment plants. Inadequate capacity in portions of the system increases the risk of wastewater backups and overflows during periods of peak flow.

Wastewater flows, both existing and projected, come from two basic sources: *sanitary flows* from homes and businesses and *infiltration and inflow (I/I)* of clean stormwater and groundwater that enter the separated sewer system. Sanitary flow (also referred to as base flow) is the only flow component intended to enter the separated wastewater system. I/I enters the separated wastewater system through cracks and other leak points that result from general degradation and damage to pipes, manholes, and other system features over time (Figure 3-1). The most common leak point for I/I is side sewers on private property. These privately owned pipes connect into collection pipes owned and operated by the 34 local agencies that are served by the regional conveyance and treatment system. See the *I/I Alternatives/Options Report* for a more detailed discussion of possible approaches to managing I/I within the region.

3.1 Why Parts of the System Are Near or At Capacity

There are multiple reasons why portions of the conveyance system are at or near capacity. They include the age of some system components, improved information about system demands from population growth and I/I, and changes in design and performance standards. Each is discussed in more detail below.

3.1.1 Portions of the System Are Well Over 40-Years Old

The regional conveyance system includes pipes and other features that were built as early as 1900, with substantial additions being made through today. The various portions of the conveyance system were constructed to meet design standards and growth projections that were available at the time they were designed and constructed. As a result, some portions of the system have reached or are reaching their maximum designed capacities.

¹ Peak Flow is the highest base flow and infiltration/inflow expected to enter a wastewater system during wet-weather at a given frequency that a treatment plant and conveyance facilities are designed to accommodate.

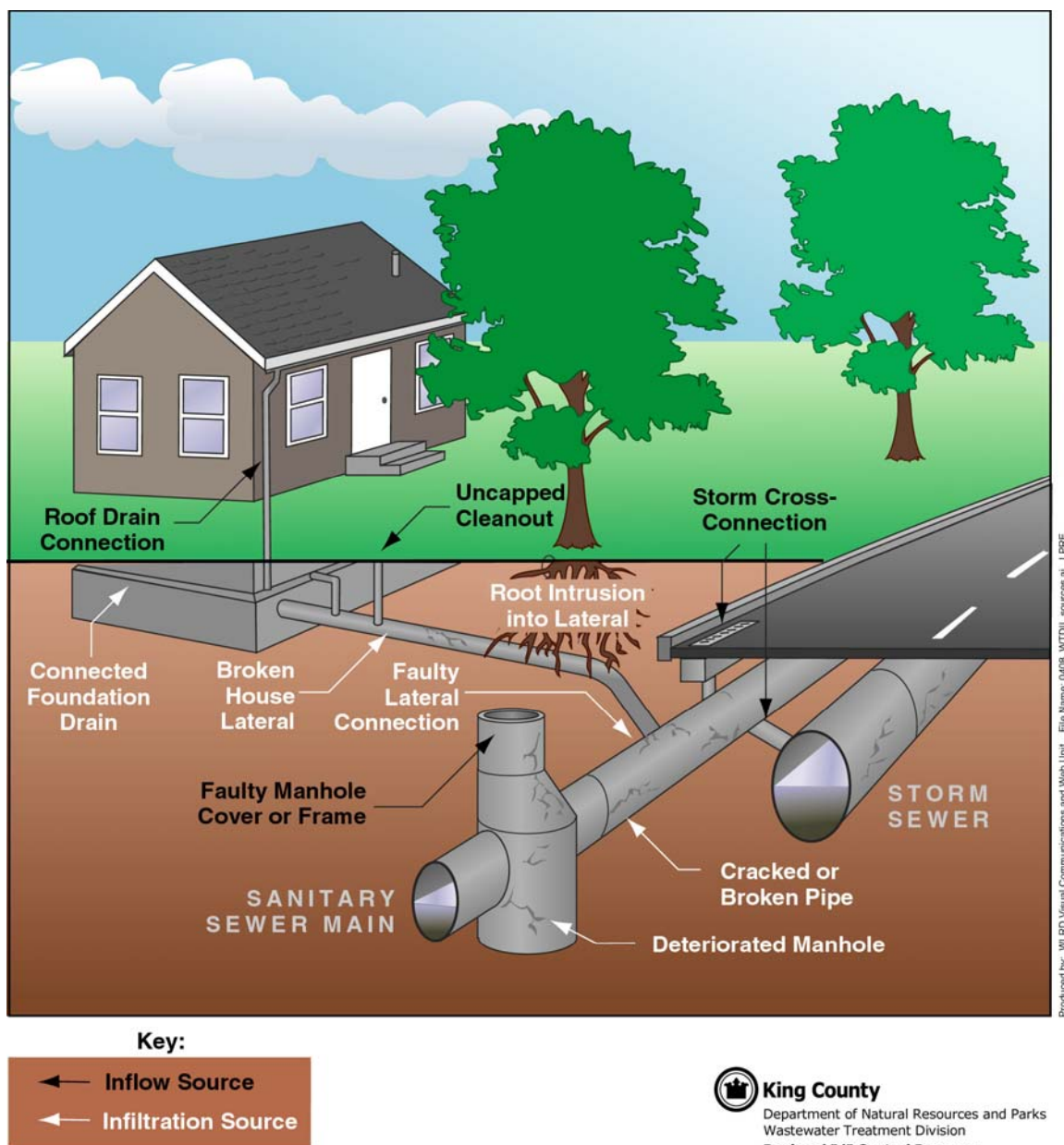


Figure 3-1. Sources of Infiltration and Inflow

3.1.2 Projections of System Capacity Have Improved

A closely related condition to the age of portions of the conveyance system is that information available about regional growth and the resulting flow projections has improved over time. Information related to population and employment growth, water consumption and conservation, rainfall, and other factors that affect wastewater flow projections has grown and become more accurate. In the past, census data, regional rainfall data, and general experience were the basis for sizing pipes and other components of the conveyance system. Today, flow monitoring data, more

specific census data, improved population and economic growth forecasts, and rainfall data obtained from meters dispersed across the region and from radar tracking of rainfall allow for more accurate projections of flow. The availability of improved data coupled with modern computer-based modeling tools allow for more comprehensive and accurate projections of wastewater flows. The results of improved analyses indicate that certain portions of the conveyance system require expansion because wastewater flows are higher than what was projected earlier.

3.1.3 The System Was Built to Varying Capacity Standards Over Time

Various components of the conveyance system were built to projected capacities that could be estimated or agreed to at the time of their development. Recommended design standards for the original Metro trunk and interceptor sewers included a peak wet-weather inflow of 2,000 gallons per acre per day (gpad) and an infiltration value of 1,200 gpad for total peak I/I values of 3,200 gpad for existing systems and 1,100 gpad for newly constructed systems.² Based on observations and modeling analysis, the peak I/I flows in the service area are greater than the 3,200 gpad standard for existing sewers and the 1,100 gpad standard for new construction that was used for design in much of the system. Therefore, this standard is no longer considered practical.

The adoption of the RWSP in 1999 established a uniform development standard for all future development. RWSP Policy CP-1 states:

“To protect public health and water quality, King County shall plan, design, and construct county wastewater facilities to avoid sanitary sewer over flows.

- 1. The twenty-year design storm shall be used as the design standard for the county’s separated wastewater system.”*

To ensure that components of the system are adequately sized for the future and the number of facility upgrades is minimized, the Wastewater Treatment Division has chosen 2050 as its design year for all new facilities and facility upgrades. The year 2050 is the projected date when the regional wastewater service area will be fully built out and all portions of the service area will be connected into the wastewater treatment system. This means that facilities are being designed to convey and treat projected 20-year peak flows between now and 2050. To avoid over-building, facility construction is being phased whenever practical. The effect of applying the 20-year peak design standard is that certain components of the conveyance system that were previously built to a different standard now require upgrades to meet the new standard.

3.2 Condition of the System

Based on the analyses conducted, most of the regional conveyance system has capacity to accommodate the 20-year peak flow through 2050. Figure 3-2 shows the regional conveyance system and identifies those portions of the system that require upgrades or expansion. Portions of the conveyance pipes (shown in purple) require expansion and eight additional pump stations (shown in pink) are expected to be needed.

² Metropolitan Seattle Sewerage and Drainage Survey, Chapter 13, 1958.

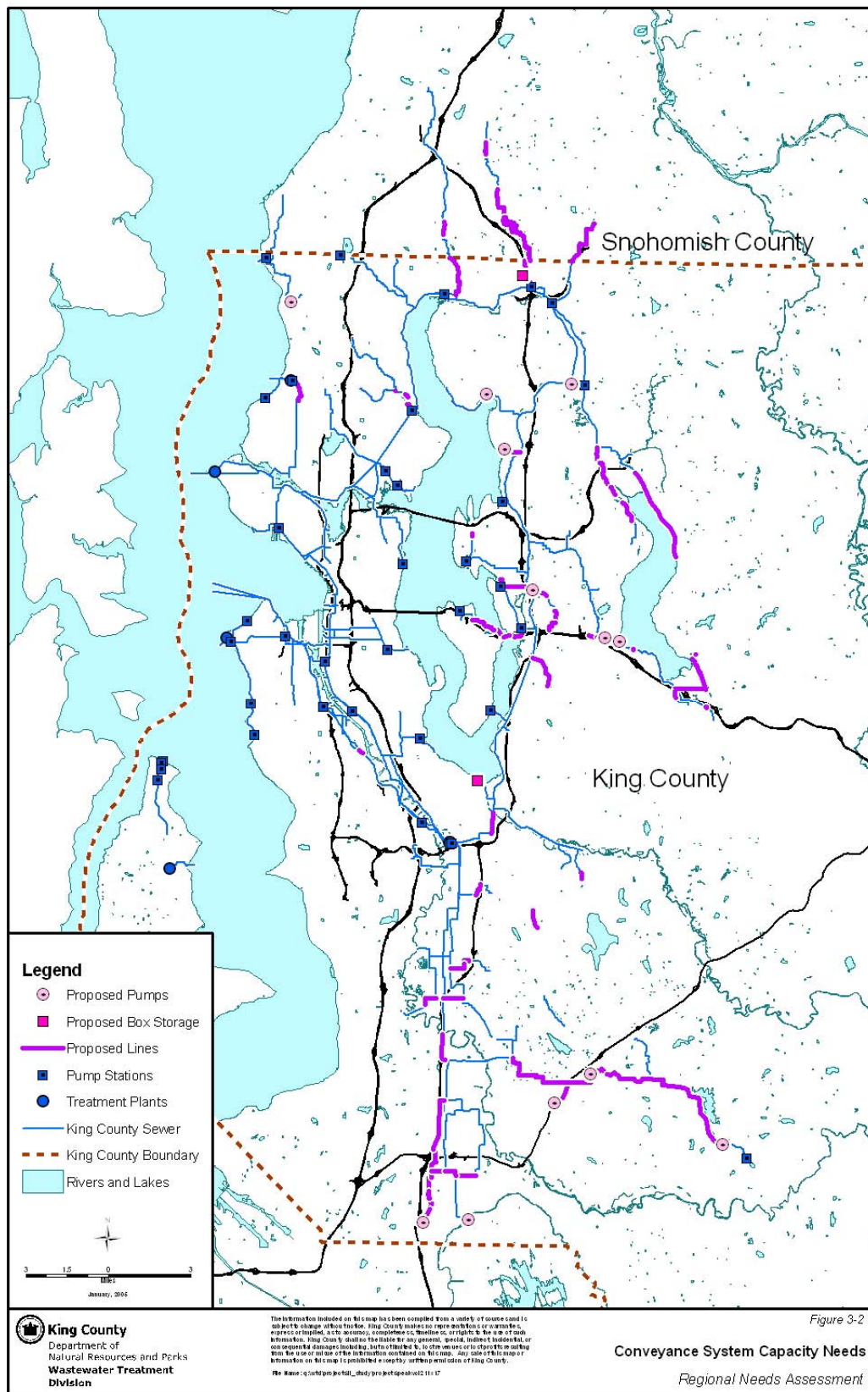


Figure 3-2. Map of Conveyance System Capacity Needs

The two factors that drive the need to expand capacity in the conveyance system are regional population growth and I/I flows within the system. Regional population and employment growth was discussed in the previous pages. The impact of I/I flows is discussed here.

I/I significantly impacts the capacity of the region's wastewater conveyance and treatment system. During storm events, I/I is by far the largest contributor to wastewater volumes that must be conveyed and treated. Figure 3-3 is a hydrograph that illustrates how I/I affects the volume of regional wastewater volumes that must be conveyed and treated. As can be seen, flow volumes can quadruple during rain events when the conveyance system must handle base flow *plus* I/I (the blue line in the figure).

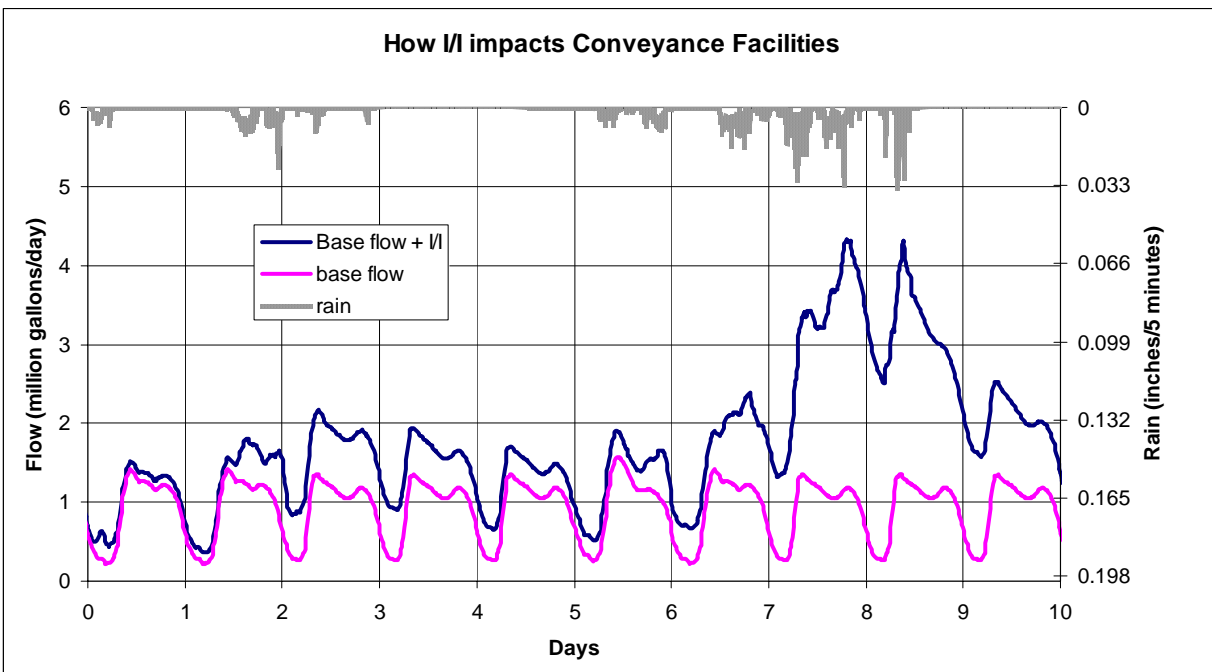


Figure 3-3. Impacts of I/I on Wastewater Flows

3.3 How the System Condition Was Assessed

To determine the condition of the conveyance system and measure its long-term capacity to direct existing and projected wastewater flows to the treatment plants, the Wastewater Treatment Division in cooperation with local agencies undertook a conveyance system flow modeling effort as part of the I/I program.

Modeling of sewage and I/I flows for the I/I control program serves as the basis for establishing the baseline of conveyance facility needs for comparison to various I/I reduction scenarios. It

establishes the I/I reduction efficiencies and characterized the regional and agency I/I levels for design flow conditions. Flow modeling provides a consistent method of estimating the peak flows generated by residents and businesses served by local agencies and, in turn, the effects of peak flows on the County conveyance system. Flow modeling also provides a means to assess the current condition of the system by calibrating to a limited set of measured data and to see how future sewer growth and existing I/I volumes will affect the King County system.

3.4 Overview of I/I Program Modeling

The general strategy for modeling I/I and sewage flows was to collect rainfall and flow data for the model and calibrate the continuous *hydrologic* portion of the model to the rainfall response for 147 “model basins” in the service area. (Model basins and their flow data are discussed in Section 3.5 of this report) Once good calibration was achieved, a long-term (60-year) rainfall data set was used to “run” each model basin to model long-term flow. The modeled long-term flows were analyzed statistically to determine the 20-year peak flow produced within each particular model basin. These peak flows from the model basins were then applied (input) to a hydraulic model of the County conveyance system. The *hydraulic* model was then run to analyze how the system performs under the 20-year existing peak flow conditions.

Once the existing 20-year peak flows for the current conditions were established (assumed to be year 2000), future flow conditions were projected. The projections involved applying assumptions related to sewer growth, existing I/I rates and I/I rates from areas to be sewer in the future, and analyzing their impacts on the County conveyance system. The results of this analysis identify needed capital improvements to the regional conveyance system. These needed capital improvements are discussed in Chapter 4.

Modeling Term Definitions:

Hydrologic model: A model used to numerically simulate the physical process of how rainfall ends up as inflow and infiltration.

Hydraulic model: A model of the actual pipes that convey the wastewater flows and I/I generated by the hydrologic model. The hydraulic model outputs flow depths and velocities within specific pipe segments and allows the evaluation of how the system performs under existing and future demands.

Basin: A geographic area that contributes flow to a specific location, usually a flow meter or a facility. The two primary types of basins used in the assessment are **model basins** and **mini basins**.

Model calibration: The process of adjusting model parameters so the model output matches the measured sewer flow for the same time period.

Peak flow by return period: A statistical analysis related to the probability that a given flow will be equaled or exceeded in a given year. The 20-year peak flow has a 1 in 20, or 5% chance, of being exceeded in any given year.

3.5 Model Selection, Data Collection, and Modeling Assumptions

The following sections detail the model selection process, the acquisition and application of data, the model calibration process, the establishment of 20-year peak flows, the assumptions related to sewered population and area growth and their application, and the eventual assessment of the needs for conveyance improvements and upgrades.

3.5.1 Model Selection

The County acquired new hydraulic modeling software, MOUSE™ (Modeling of Urban Sewers) and a personal computer (PC) based model with a graphic interface to GIS. County management and staff decided to move away from an in-house model to a commercially available modeling package because it allows modeling results to be easily shared and analyzed by the County and local agencies. Selection of the MOUSE™ modeling software was the result of a detailed competitive selection process where three software packages were evaluated for technical capability and cost. The model selection process is detailed in *Appendix A1*.

3.5.2 Data Collection

The I/I modeling required the following data:

- Flow data
 - Including varying groundwater conditions
- Rainfall and evaporation data
 - Including large rain storms to trigger I/I response
 - Including several storms to ensure simulation of different rainfall conditions
- Sewer basin data
 - Sewered area
 - Dry weather flow patterns
- Conveyance system specifications

Flow Data

To quantify both base and I/I flows, “model basins” and “mini basins” were identified and mapped by the County and local agencies.:

- *Model basins* represent the sewered area flowing to a specific flow meter location. Each Model basin consists of approximately 1,000 sewered acres and 100,000 lineal feet of pipe. There are 147 model basins. Some of the model basins straddle agency boundaries due to agreements between agencies to “pass through” flows to King County.

- *Mini basins* are a further sub-division of model basins that geographically isolate variation in I/I flow rates within the model basins. There are 775 mini basins. They average 150 acres with 22,000 lineal feet of pipe.³

To measure and project base flow and I/I, flow meters were installed throughout the regional service area to measure flows during dry-weather and wet-weather periods. Flows during dry-weather periods are typically base flows only. Wet-weather periods typically consist of **both** base flows and I/I. Metering flows during both dry and wet-weather periods makes it possible to develop separate measurements for base flow and I/I. The data gathered from flow meters were used to calibrate the hydrologic component of the conveyance system model and to establish non-storm flow patterns to characterize the base sewage flow from specific portions of the service area.

Over 800 flow meters were installed and monitored by the County during the 2000–2001 wet season. Due to a drought, the monitoring effort was repeated during the 2001–2002 wet season to obtain accurate wet-weather flow data. (The wet season was defined as November 1 through January 15.) The locations of flow meters were carefully chosen so that the service area could be consistently delineated to support the use of the computer model, provide clarity and accuracy, and allow interpretation and application for other uses. Three types of meters were placed throughout the service area:

- **Long-term meters**—75 long-term meters were placed at strategic locations in the County conveyance system where full-time flow data would be available for the next several years. This would allow for monitoring and assessment of system operation to further calibrate and validate the system model.
- **Modeling meters**—94 meters were placed at the outlets of model basins in order to provide flow information for calibration of the hydrologic model. Modeling meters collected data only during the wet weather season. Some of the long-term meters also functioned as modeling meters for about 160 basins.
- **Mini-basin meters**—638 meters, in addition to the above meters, were placed farther upstream in mini basins to isolate the flow response of smaller areas. These were installed during the wettest portion of the wet-weather season.

The locations of the flow meters are shown in Figure 3-4. The flow meters measure both the depth and velocity of wastewater flows in pipes. Conducting flow monitoring at the mini basin level helps to assure that wet-weather performance was measured equitably, both system-wide and within each local agency's sewer collection service area. Flow monitoring in all of the mini basins was conducted simultaneously so that monitoring results were comparable.

³ There is an average of five model basins per local agency, with a maximum of 17 model basins in Bellevue. The average number of mini basins within a model basin is five. The maximum number of mini basins per model basin is 13, and the minimum number is one (the model basin and the mini-basin are the same). The average number of mini-basins per agency is 23; the maximum is 117, once again in Bellevue. Five local agencies have just one mini basin.

The flow monitoring data gathered provides an accurate picture of current flows in local agency collection systems and the County's regional conveyance system. Projecting future flows required calibration of the hydrologic portion of the model to the measured flows.

Rainfall and Evaporation Data

Rainfall data throughout the regional wastewater service area were collected for the 2000-2001 and 2001-2002 wet seasons. Data were gathered from 64 rain gauges. The rain gauge data were used in combination with CALAMAR (Calcul de lames d'eau a l'aide due radar [*calculating rain with the aid of radar*]) radar images to define varying rainfall intensities throughout the service area.

Rainfall data were used to calibrate the hydrologic model and establish storm flow patterns to characterize I/I patterns that cause peak flows during storm events. A continuous time series of rainfall data was a required input for the hydrologic modeling performed. Local rainfall data coupled with radar-based rainfall intensity data were used for the model calibration. For prediction of the 20-year peak I/I flow, a 60-year rainfall record was used as a reasonable approximation of future rainfall frequency and intensity.

The 60-year rainfall record is an extended time series (ETS) based on Seattle-Tacoma (Sea-Tac) International Airport precipitation records. The ETS records represent the longest continuous record of rainfall data for the area. For modeling purposes, it was assumed that the past ETS records are representative of future rainfall patterns that are likely to occur in the service area. Such a record is valuable because of the strong influence that antecedent conditions have on I/I flow entering a pipe. The most effective way to simulate antecedent conditions is to utilize a model simulation that uses an actual series of measured rainfall. One of the primary features of the ETS rain data is that it contains scaled rainfall data sets based on zones of mean annual precipitation (MAP zones). This allows the model to account for locations within the service area that have greater rainfall amounts than Sea-Tac but no long-term rainfall record. For more information on the ETS and its application for this project, see *Appendix A2*.

Evaporation data needed for the continuous hydrologic modeling process were obtained from Washington State University's public agricultural weather system (PAWS) Puyallup weather station. This data source provides commonly used data for hydrologic modeling in the Puget Sound region. Evaporation data used for the long term ETS model runs were supplied with the rainfall files and were generated based on long-term Puyallup weather station data.

Sewer Basin Data

Population and sewered area information is a combination of available data and analyses of parcel data, aerial photos, zoning, and land-use information that identifies the sewered portion of the wastewater service area. The resulting product was GIS-based information about the service area previously unavailable at the level that it now exists. Along with its value for model calibration, the results of the analyses let us clearly apply growth assumptions to future I/I and base flow scenarios.

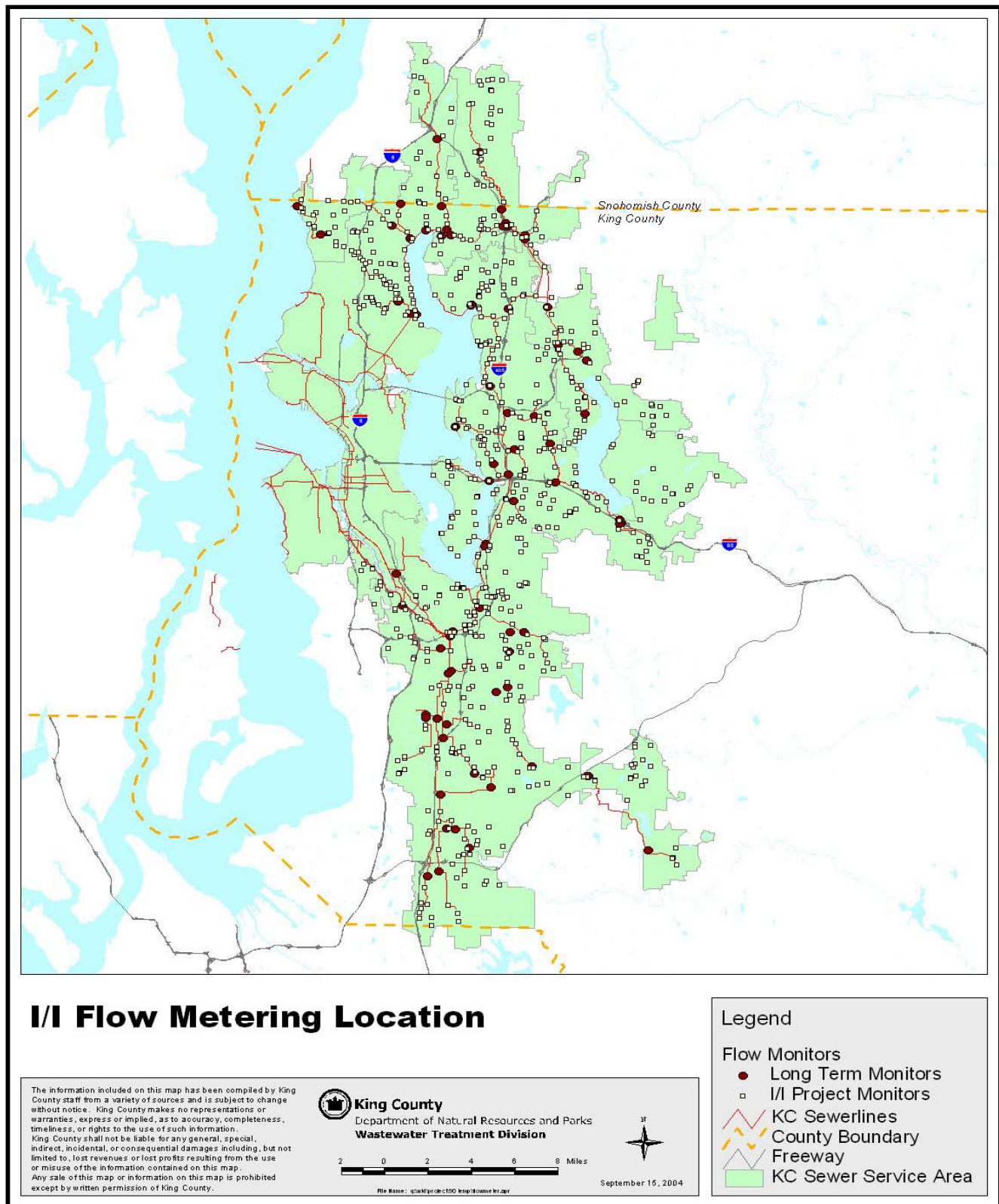


Figure 3-4. Flow Meter Locations

Population and sewered area information is a necessary input for both hydrologic and hydraulic modeling. The information includes specific population data and geographic information about the size of the sewered area. Combined, these two factors contribute to the base sewage flow and I/I generated in the 147 model basins.

The sewered area information was key and needed a certain level of accuracy due to the characterization of I/I flows in King County Code Section 28.84.050 (K) (3), which states, in part, that “an additional charge will be made for quantities of water other than sewage and industrial waste hereafter entering those sewers constructed after January 1, 1961.” The value of the peak I/I flow can be very sensitive to how the sewered area is defined. Large open spaces, like parks, are not sewered and do not contribute to I/I flows in the sewer system. It was important to identify and isolate these areas in order to calculate accurate I/I flow and base flows. For more information characterizing these areas, see *Appendix A3*.

Conveyance System Specifications

Conveyance system specifications include specific physical details (such as pipe sizes, elevations, pump station capacities, and connection points) about the conveyance system. Most of the necessary data were available from the County’s GIS database. Other details were provided by local agencies. The specifications are a key input into the hydraulic model, which measures and projects how different components of the conveyance system perform when subject to sewage flows and I/I following storm events.

3.5.3 The Model Calibration Process

Calibration of the model is necessary to test the accuracy of its outputs. Calibration was accomplished by comparing model results to actual measured flow data. Both the hydrologic and hydraulic components of the model were calibrated to the two wet seasons of flow data collected in 2000–2002, and to the dry-weather sewage flow pattern.

Calibration involved adjusting wet-weather flow parameters in the model until the model output matched actual measured wet-weather flows. The dry-weather flow calibration process involved taking measured sewer flow data from dry-weather periods and identifying diurnal patterns⁴ based on measured flows on weekdays and weekends. The establishment of dry-weather diurnal patterns throughout the week allowed the model to distinguish between rainfall-induced peak flows and flows generated by periods of high water consumption in different parts of the service area. As an example, non-storm peak diurnal flows from the Sammamish Plateau on weekends are higher than storm-induced peaks on weekdays.

Figure 3-5 below is a graphical example of how the calibrated model output matches the measured flow data for a variety of storms in the 2001–2002 monitoring period.

⁴ Diurnal patterns are the regular rise and fall in daily consumptive use of water and production of wastewater. Varying land uses within sewer basins have a large impact on diurnal patterns and volume. (i.e., different mixes of residential, commercial, and industrial land uses).

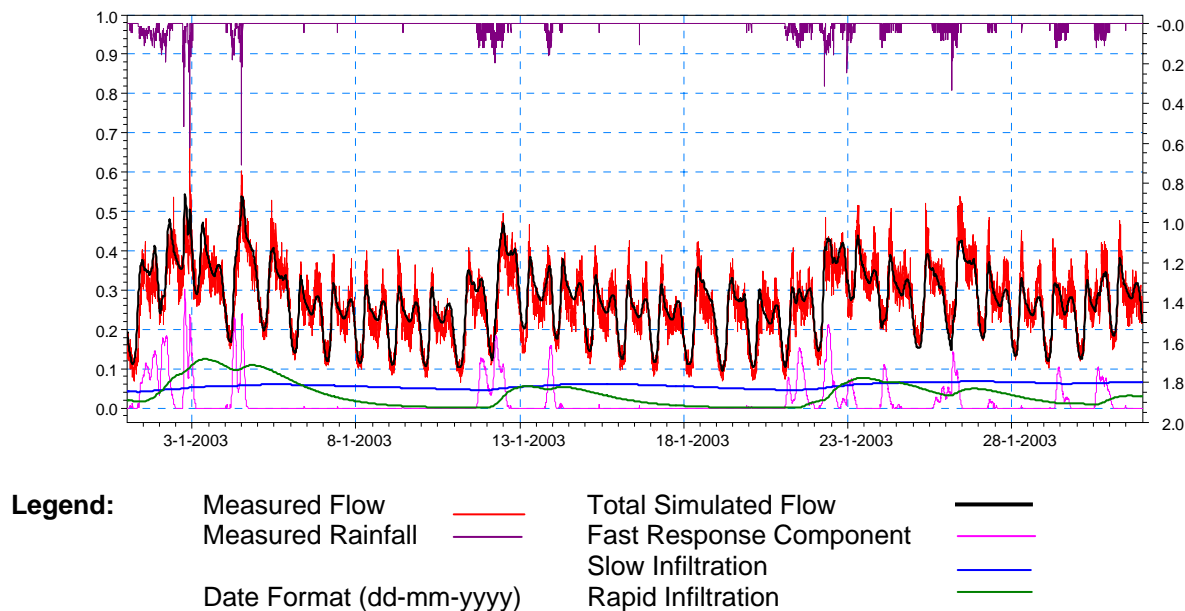


Figure 3-5. Comparison of Modeled Flow Data to Measured Flow Data

Once the models were calibrated, long-term simulations were run using the data inputs described above. The output from the long-term simulations was analyzed to determine the probability of a given peak flow being exceeded during a given year. This probability was then used to calculate the return period of peak flow. More detail on the calibration, dry weather calibration, and estimation of peak flows is contained in *Appendix A4*.

3.5.4 Model Verification Through use of the Hydraulic System Model

The next key element for modeling was inputting the flows into a hydraulic model of the County system of conveyance facilities (pipes, pumps, and storage) so that the current state of the system could be evaluated. This involved using the calibrated outputs from the hydrologic model along with base sewage flow data. The modeled flows were inputted into the hydraulic model in the appropriate physical locations. This was necessary because the model basins vary from a single connection point to the conveyance system to as many as nine connection points per model basin. Using flows from the calibration time period allowed us to spot check the original model basin calibrations by comparing combined model basin flows to actual flow measurements in the system. Comparing these flows allows the County to make adjustments to both base sewage flows and I/I model parameters to better characterize the base sewage and I/I contributions to the system.

Once good agreement was reached in the modeled versus measured flows, 20-year peak flow demands on the system were established by making long-term model runs of the hydraulic model to establish the current performance of the County conveyance system relative to the peak flow demands that currently impact the system.

3.6 Projecting Peak Flows into the Future

Ongoing wastewater flow and rainfall monitoring efforts and use of a computer-based conveyance system model provide the basis for establishing the current conditions of the wastewater conveyance system, described above, and for projecting future flows. These projected flows are the basis for identifying the needed conveyance system improvements described in Chapter 4.

The projected peak flow rates are a combination of base sewage increases due to growth, existing I/I rates, and I/I rates from newly sewered areas and I/I from degradation of existing and new sewers. The planning assumptions are applied by decade to each model basin and then compared to the capacity of the specific conveyance elements affected by the growth. Once the model assesses that elements of the system are under capacity relative to the demand, the time of the exceedence is noted and a capacity alternative is formulated to provide the needed capacity under the saturation condition (2050) 20-year return period peak flows. The capacity alternatives are typically pump station replacement or upgrade, parallel or replacement of gravity sewer lines, or storage facilities to temporarily store excess I/I flows until peak flows subside and there is enough capacity to safely convey the flows downstream. The chosen capacity upgrades may be one or some combination of pumps, pipes, or storage and is assumed to be the lowest cost alternative. These assumed conveyance costs form the baseline for comparison to I/I reduction costs and benefits.

3.6.1 Base Sewage Flow Growth

Growth in sanitary or base flow volume over time depends on changes in population and employment in the service area, septic conversions to sewers, and changes in water use levels through conservation efforts. Based on these factors, base flow in the regional service area is expected to grow at a steady rate through 2050.⁵ Currently, base flow in the regional wastewater system is approximately 75-million gallons per day (mgd). Through urban growth and septic conversions, base flow is projected to grow to over 120 mgd by 2050. Figure 3-6 illustrates the projected growth rate in base flow for the region. Note that the projected growth in base flow through 2010 is relatively flat. This is due to the expected positive influence of current water conservation efforts. Water conservation levels are expected to remain constant after 2020.

Of the growth factors described above, growth in residential sewered population (either from new development or septic conversions) has the biggest effect on growth in base flow. Figure 3-7 highlights the differences in the projected residential, commercial, and industrial growth rates within the regional service area.

⁵ The year 2050 is the established planning horizon for the wastewater treatment system.

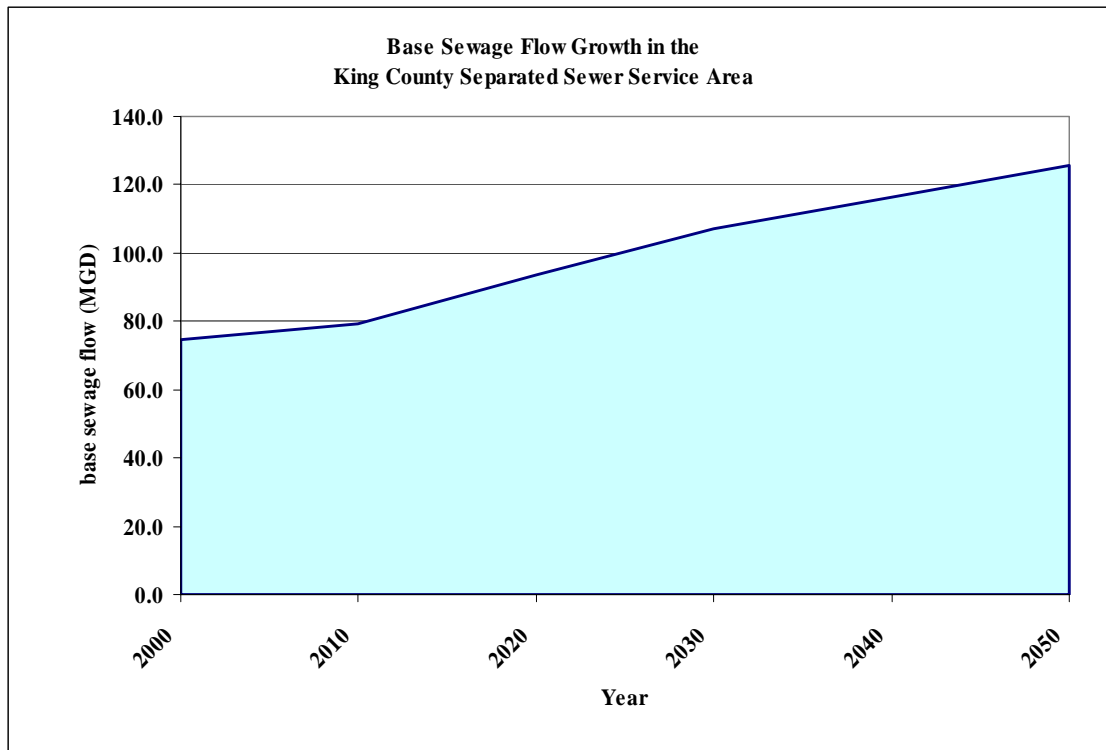


Figure 3-6. Projected Growth in Base Flow

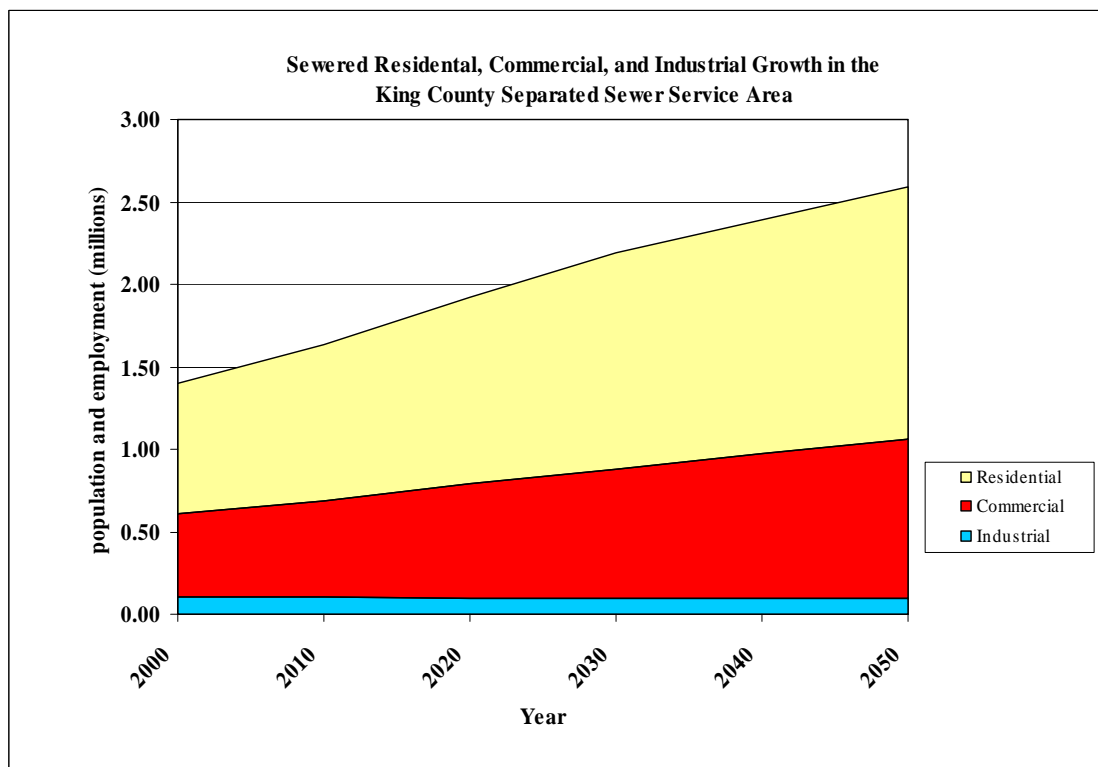


Figure 3-7. Residential, Commercial, and Industrial Growth Rates

3.6.2 I/I Growth

Growth in I/I comes from two major components: degradation of existing sewers and I/I from new sewered areas. I/I in the currently sewered areas is established based on modeling of the current conditions. Assumptions for I/I anticipated from areas sewered in the future are based on modeling results from areas sewered since 1990. The sewered area analysis described earlier in the report allows us to identify how some conveyance facilities are affected more than others in the service area by how much capacity for sewered growth exists in the area served by the facility.

Degradation or the increase of I/I into the sewer system is expected to occur over time at a rate based on historical observation.

3.7 Planning Assumptions

Planning assumptions are needed to estimate the size, timing, and costs of new conveyance system components. The events that drive the timing, sizing, and costs of facilities occur in the future and require assumptions to arrive at answers.

Following completion of I/I reduction pilot projects in early 2004, local agencies (via MWPAAC's Engineering and Planning Subcommittee) and the County used a collaborative process to discuss and agree upon a set of assumptions. Table 3-1 summarizes several of the more significant planning assumptions. See *Appendix A5* for a detailed description of all planning assumptions.

Table 3-1. Planning Assumptions for I/I Modeling

Sensitivity Factor	I/I Modeling Assumption
Water conservation (base flow projections)	10% reduction by 2010, no additional reduction thereafter
Septic conversion	90% of unsewered but sewerable area in 2000 sewered by 2030; 100% by 2050
New system I/I allowance	1,500 gallons per acre per day (gpad)
Design flow	20-year peak flow, based on SeaTac 60-year rainfall record, adjusted per annual average rainfall over each part of the service area
Degradation	7% per decade starting from year 2000 up to 28% for existing pipe; 7% per decade starting after date of construction up to 28% for new construction
Sizing of facilities	Design flow at saturation plus 25% safety factor (when sizing facilities, a safety factor of 25% of additional capacity will be used)
Discount rate	6%

Sensitivity Factor	I/I Modeling Assumption
Inflation rate	3%
Operation and maintenance analysis	<p>Update the following from RWSP:</p> <ul style="list-style-type: none">• New pipes: 15 cents per lineal foot annually• New pump stations: \$4,104 per mgd + \$60,384• New storage facilities: \$34,091 per MG + \$4,546• Treatment plants: \$15,000–\$30,000 per mgd of average annual flow reduction (plant specific); covers energy and disinfection costs